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Engineering Directorate Safety Note Dual Channel Highly Oriented Pyrolytic Graphite Diagnostic II EDSN10-000003

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Disclaimer

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Engineering Directorate Safety Note

Dual Channel Highly Oriented Pyrolytic Graphite Diagnostic II
for use at LLE
EDSN10-000003-AA

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Section A – Scope and Equipment (or System) Description

The Dual Channel Highly Oriented Pyrolytic Graphite II (DC HOPG II) diagnostic is mounted in a TIM (Ten-Inch Manipulator) system on the Omega-60 or Omega-EP laser facilities at the University of Rochester Laboratory for Laser Energetics (LLE), when in use, see Fig. 1. The Spectrometer assembly, shown in Fig. 2, is constructed mostly of Aluminum 6061-T6 with SS threaded inserts.

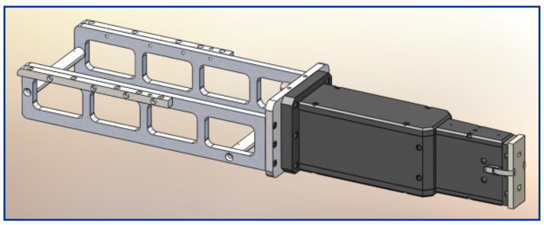


Fig. 1. The HOPG with TIM interface

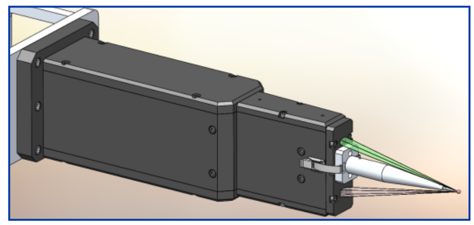


Fig. 2. The HOPG Spectrometer assembly

Section B – Operational Hazards

Failure of the DC HOPG II device or device mechanical support components could cause injury to personnel, damage to equipment, and may have significant impact on programmatic schedule and cost.

There are no electrical hazards in the DC HOPG II device.

Section C – Operational Procedure

Use of the DC HOPG II at LLE is governed by LLE procedure D-TX-P-026 Rev. B. See Appendix B – DC HOPG Operations Procedure.

Section D – Design Calculations

The analyses of the HOPG as compiled in this safety note can be split up into the following subsystems: The TIM Interface, the HOPG and TIM Mounting Interface, and the HOPG Spectrometer Assembly.

Each of these subsystems contains numerous load path elements as enumerated in Fig. 3 and Table 1.

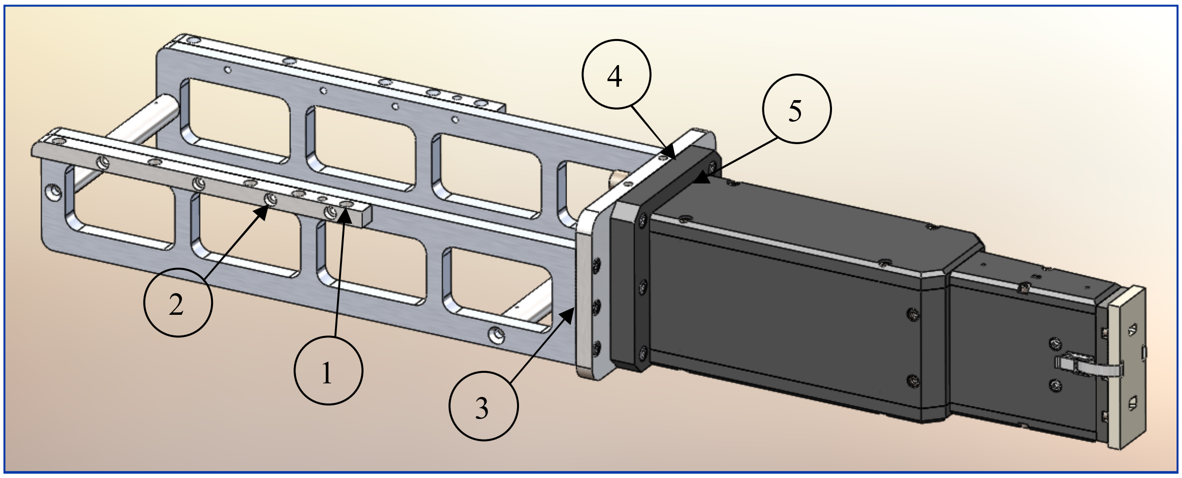


Fig. 3. HOPG Load Path elements.

Table 1: Load path elements.

1	TIM Mounting Rail (top left mounting rail) to TIM Boat	Ten 10-32 SS fasteners	App. A
2	TIM Mounting Frame (TIM mounting rail) to TIM Mounting Rail (top left mounting rail)	Eight 10-32 SS fasteners	App. A
3	TIM Mounting Frame (TIM mount rail) to TIM Mounting Plate	Six ¼"-20, grade 5 fasteners	App. A
4	TIM Mounting Plate to HOPG Mounting Plate (rear lead shield)	Six ¼"-20, grade 5 fasteners	App. A
5	HOPG Mounting Plate (rear lead shield) to Spectrometer Assembly Side Plates (right rear side plate & left rear side plate)	Eight 10-32 SS fasteners	App. A

The TIM boat structure is outside of the scope of this safety note. This safety note includes everything from the TIM Mounting Rails forward. The maximum load rating for diagnostics mounted to the TIM is 100 lb, per LLE drawing D-EA-C-94, Rev. C included in Appendix I. The HOPG II weighs only 18.5 lb, therefore it meets this criterion.

The following table lists the factors of safety for each load path item:

Table 2: Factors of safety for the HOPG.

Configurations	Stress (ksi)	Yield Stress (ksi)	Safety Factor (yield)	Required Safety Factor*
1.1 TIM Rail/ TIM Boat Bolt Stress, Von Mises	0.59	30.0	50.4	3 SY
1.2 TIM Rail/ TIM Boat Tapped Holes, Shear	0.40	20.2	49.9	3 SY
1.1a TIM Rail/ TIM Boat Bolt Stress, Von mises	0.72	30.0	41.8	1 SSY
1.2a TIM Rail/ TIM Boat Tapped Holes, Shear	0.49	20.2	41.4	1 SSY
2.1 TIM Frame/ TIM Rail Bolt Stress, Von Mises	0.77	30.0	39.1	3 SY
2.2 TIM Frame/ TIM Rail Tapped Holes, Shear	0.52	20.2	38.6	3 SY
2.1a TIM Frame/ TIM Rail Bolt Stress, Von mises	0.93	30.0	32.3	1 SSY
2.2a TIM Frame/ TIM Rail Tapped Holes, Shear	0.63	20.2	31.9	1 SSY
3.1 TIM Frame/ TIM Plate Bolt Stress, Von Mises	0.33	30.0	90.3	3 SY
3.2 TIM Frame/ TIM Plate Tapped Holes, Shear	0.09	20.2	221.1	3 SY
3.1a TIM Frame/ TIM Plate Bolt Stress, Von mises	0.47	30.0	73.7	1 SSY
3.2a TIM Frame/ TIM Plate Tapped Holes, Shear	0.11	20.2	181.1	1 SSY
4.1 TIM Plate/ HOPG Plate Bolt Stress, Von Mises	0.30	30.0	99.6	3 SY
4.2 TIM Plate/ HOPG Plate Tapped Holes, Shear	0.08	20.2	253.8	3 SY
4.1a TIM Plate/ HOPG Plate Bolt Stress, Von mises	0.37	30.0	81.1	1 SSY
4.2a TIM Plate/ HOPG Plate Tapped Holes, Shear	0.10	20.2	207.7	1 SSY
5.1 HOPG Plate/ Side Plate Bolt Stress, Von Mises	0.52	30.0	57.2	3 SY
5.2 HOPG Plate/ Side Plate Tapped Holes, Shear	0.09	20.2	215.9	3 SY

Configurations	Stress (ksi)	Yield Stress (ksi)	Safety Factor (yield)	Required Safety Factor*
5.1a HOPG Plate/ Side Plate Bolt Stress, Von mises	0.64	30.0	47.1	1 SSY
5.2a HOPG Plate/ Side Plate Tapped Holes, Shear	0.11	20.2	178.4	1 SSY

* SY=Static Yield, SU=Static Ultimate, SSY=Static+Seismic Yield, SSU=Static+Seismic Ultimate

1) The top left and top right mounting rails are connected to the TIM boat (the TIM boat is LLE equipment) using 10 10-32 stainless steel fasteners and helicoil inserts. The fasteners will be analyzed under both static and seismic loading conditions. The SRSS method will be used to combine seismic response values. Conservatively, only two of the ten fasteners will be used in the calculations. No information is known about the inserts in the TIM boat, therefore the thread shear will be calculated based on a 10-32 thread directly into aluminum (building additional conservatism into the calculations).

2) The top left and top right mounting rails are connected to the TIM mounting rail using 8 10-32 stainless steel fasteners and helicoil inserts. The fasteners will be analyzed under both static and seismic loading conditions. The SRSS method will be used to combine seismic response values. Conservatively, only two of the eight fasteners will be used in the calculations.

   The TIM mounting rail will not be analyzed. In EDSN09-500001-AB the rail was analyzed by inspection. The weight of the diagnostic used in those calculations was three times the weight of the DC HOPG II and the distance to the CM was also greater. In those conservative calculations, the minimum cross sectional area of the rails was used to calculate a factor of safety, based on seismic loading conditions. The maximum von mises stress was 235.01 psi, resulting in a factor of safety of 148.93.

3) The HOPG assembly is mounted to the TIM mounting plate, which is connected to the TIM mounting rails, using six ¼”-20 fasteners. The fasteners are assembled through the TIM mounting plate and threaded into the TIM mounting rails. Conservatively, only the top two fasteners are used for tension calculations. The maximum shear, in the aluminum threads, is 668 psi, resulting in a factor of safety of 30.

4) The HOPG is mounted to the 6061 aluminum TIM mounting plate, using six ¼”-20 fasteners. The fasteners are assembled through the rear lead shield and threaded into the TIM mounting plate. For conservations, only the top two fasteners are used for tension calculations.

5) The HOPG Spectrometer box is fabricated from Aluminum 6061-T6 with stainless steel threaded inserts. The side plates of the spectrometer box assembly are fastened to the rear lead shield using 8 10-32 x 0.75" SS SHCS into SS threaded inserts. The spectrometer box will be analyzed under both static and seismic loading conditions. Conservatively, only the top two 10-32 screws will be used in the static calculations. The SRSS method will be used to combine seismic response values.

The following table lists the torque value for each fastener:

Table 3: Torque values for the DC HOPG II.

Item #	Screw Size	Designed Length of Engagement	Calculated Length of Engagement	Female Threads	Recommended Torque (in-lbf)
1	10-32	0.475"	0.094	Al 6061-T6 w/ SS Helicoil Inserts	14.0
2	10-32	>0.094"	0.094	Al 6061-T6 w/ SS Helicoil Inserts	14.0
3	¼"-20	0.25"	0.25	Al 6061-T6	28.5
4	¼"-20	0.25"	0.25	Al 6061-T6	28.5
5	10-32	0.31"	0.31	Al 6061-T6 w/ SS Helicoil Inserts	13.5

Section E - Testing Requirements

No Testing Requirements.

Section F – Labeling Requirements

The equipment needs to be labeled per the requirement in LLE Seismic Criteria NIF-0116027-AC, with the EDSN number "EDSN10-000003-AA". If labeling is not possible, the equipment must be bagged and tagged with the EDSN number "EDSN10-000003-AA".

The equipment needs to be labeled per the requirement in LLE Seismic Criteria NIF-0116027-AC, "For Use at LLE Only". If labeling is not possible, the equipment must be bagged and tagged with the message "For Use at LLE Only".

Section G – Associated Procedures

None associated.

Section H – References

1. *Engineering Design Safety Standards Manual,* M-102, Lawrence Livermore National Laboratory, 2009.

2. *Recommended Seismic Criteria for LLNL Equipment Located at LLE*, NIF 0116027-AC, 12/18/2009

Appendix A – Calculations

System Weight & CG:

$W_{spect} := 18.5lbf$ — Weight of Spectrometer Assembly (Obtained from M. Saculla CAD Model 1/4/10)

$CG_{spect} := 11.646in$ — from the Tooling Balls. CG = 20.896" from the last set of rollers on TIM (Obtained from M. Saculla CAD Model 1/4/10)

Material Properties:

$\sigma_{y\_Al6061T6} := 35000psi$ — Yield strength of Aluminum 6060-T6

$\sigma_{y\_SS\_bolt} := 30000psi$ — Yield strength of SS bolt

Seismic:

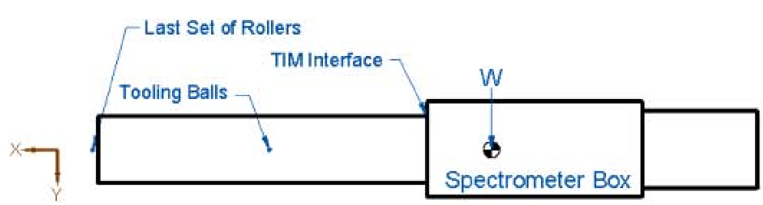
$Z := 0.15$ $\quad I := 1.0$

$C_p := 2$ — Elevated equipment

$SD_h := Z \cdot I \cdot C_p = 0.3$ — Horizontal Seismic Demand

$SD_v := \left(\frac{2}{3}\right) Z \cdot I \cdot C_p = 0.2$ — Vertical Seismic Demand

$SD_x := SD_h = 0.3$ $\quad SD_y := SD_v = 0.2$ $\quad SD_z := SD_h = 0.3$



Axis used for seismic calculations

1. TIM Mounting Rail (top left mounting rail) to TIM Boat

Given:

$W_1 := W_{spect} = 18.5 \cdot lbf$ Dead weight of Spectrometer Assembly

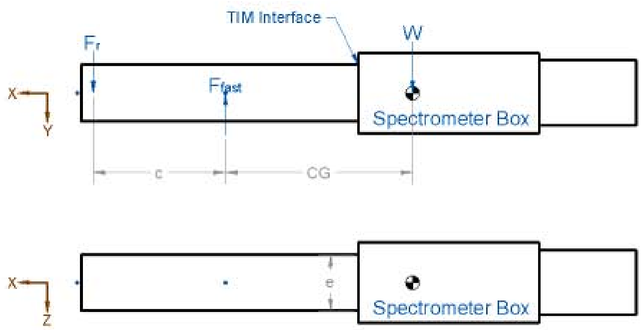
$CG_1 := CG_{spect} - 0.625in = 11.021 \cdot in$ CG of Spectrometer Assembly

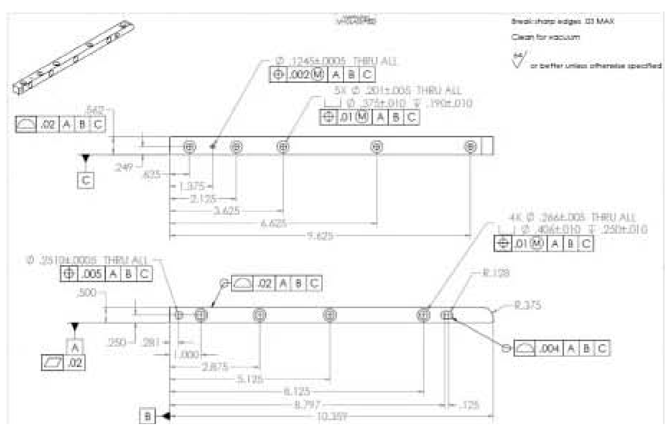
$d_{1c} := 9.0in$ Distance between fasteners (x-direction)

$d_{1e} := 3.5in$ Distance between fasteners (z-direction)

$n_{t1} := 2$ Number of fasteners used for tension only

$n_{tot1} := 10$ Total number of fasteners





1.1 10-32 Fasteners:

$D_{n1} := 0.19in$ Nominal diameter of 10-32

$TPI_1 := \frac{32}{in}$

$D_{m1} := D_{n1} - \frac{1}{TPI_1} = 0.159 \cdot in$ Mean diameter of fastener

$A_{m1} := \frac{\pi \cdot (D_{m1})^2}{4} = 0.02 \cdot in^2$ Area of fastener

$T_1 := \frac{W_1 \cdot CG_1}{d_{1c} \cdot n_{t1}} = 11.327 \cdot lbf$ Tensile force acting on fastener

$\sigma_1 := \frac{T_1}{A_{m1}} = 572.272 \cdot psi$ Tensile stress in fastener

$\tau_1 := \frac{W_1}{n_{tot1} \cdot A_{m1}} = 93.466 \cdot psi$ Shear stress in fastener

$\sigma_{vm1} := \sqrt{{\sigma_1}^2 + 3 \cdot (\tau_1)^2} = 594.73 \cdot psi$ Von Mises stresses in fastener

$\sigma_{allow1bolt} := \sigma_{y\_SS\_bolt} = 3 \times 10^4 \cdot psi$ Yield strength of SS SHCS

$SF_1 := \frac{\sigma_{allow1bolt}}{\sigma_{vm1}} = 50.443$ Static Factor of Safety for Fastener

1.1a Seismic Analysis:

$SD_{x1} := SD_x \cdot W_1 = 5.55 \cdot lbf$

$SD_{y1} := SD_y \cdot W_1 = 3.7 \cdot lbf$

$SD_{z1} := SD_z \cdot W_1 = 5.55 \cdot lbf$

X-Dir:

$\tau_{1SDx} := \frac{SD_{x1}}{n_{tot1} \cdot A_{m1}} = 28.04 \cdot psi$ Shear stress in fastener, including seismic

$\sigma_{vm1SDx} := \sqrt{3 \cdot (\tau_{1SDx})^2} = 48.566 \cdot psi$ Von Mises stresses in fastener, including seismic in the X-direction

Y-Dir:

$T_{1SDy} := \frac{(W_1 + SD_{y1}) \cdot CG_1}{d_{1c} \cdot n_{t1}} = 13.593 \cdot lbf$ Tensile force acting on fastener, including seismic

$\sigma_{1SDy} := \frac{T_{1SDy}}{A_{m1}} = 686.727 \cdot psi$ Tensile stress in fastener, including seismic

$\tau_{1SDy} := \frac{(W_1 + SD_{y1})}{n_{tot1} \cdot A_{m1}} = 112.159 \cdot psi$ Shear stress in fastener, including seismic

$\sigma_{vm1SDy} := \sqrt{\sigma_{1SDy}^2 + 3 \cdot (\tau_{1SDy})^2} = 713.676 \cdot psi$ Von Mises stresses in fastener, including seismic in the Y-direction

Z-Dir:

$T_{1SDz} := \frac{SD_{z1} \cdot CG_1}{d_{1c} \cdot \left(\frac{n_{tot1}}{2}\right)} = 1.359 \cdot lbf$ Tensile force acting on fastener, including seismic

$\sigma_{1SDz} := \frac{T_{1SDz}}{A_{m1}} = 68.673 \cdot psi$ Tensile stress in fastener, including seismic

$\sigma_{vm1SDz} := \sqrt{\sigma_{1SDz}^2} = 68.673 \cdot psi$ Von Mises stresses in fastener, including seismic in the Z-direction

$\sigma_{vm1SD} := \sqrt{\sigma_{vm1SDx}^2 + \sigma_{vm1SDy}^2 + \sigma_{vm1SDz}^2} = 718.615 \cdot psi$ Von Mises stresses in fastener, including seismic

$SF_{1SD} := \frac{\sigma_{allow1bolt}}{\sigma_{vm1SD}} = 41.747$ Seismic Factor of Safety for Fastener

1.2 Thread Shear in the Tapped Holes:

$\sigma_{yield1.2} := \sigma_{y\_Al6061T6} = 3.5 \times 10^4 \cdot psi$ Yield strength of Aluminum

$D_{n1} = 0.19 \cdot in$ Information on threaded inserts is unknown, assume no inserts (this is a conservative assumption)

$Le_1 := \frac{3}{32} in = 0.094 \cdot in$ Length of engagement unknown, assume 3 threads

$A_{s1} := \frac{\pi \cdot D_{n1} \cdot Le_1}{2} = 0.028 \cdot in^2$ Shear area of female threads

$\tau_{thread1} := \frac{T_1}{A_{s1}} = 404.833 \cdot psi$ Shear stress in female threads

$SF_{thread1} := \frac{\sigma_{yield1.2}}{\sqrt{3} \cdot \tau_{thread1}} = 49.915$ Factor of Safety for Female Threads

1.2a Seismic Analysis:

X-Dir:

$$\tau_{thread1\,SDx} := \frac{SD_{x1}}{n_{tot1} \cdot A_{s1}} = 19.836 \cdot psi$$

Shear stress in female threads, including seismic in the X-direction

Y-Dir:

$$\tau_{thread1\,SDy} := \frac{T_{1\,SDy}}{A_{s1}} = 485.799 \cdot psi$$

Shear stress in female threads, including seismic in the Y-direction

Z-Dir:

$$\tau_{thread1\,SDz} := \frac{T_{1\,SDz}}{A_{s1}} = 48.58 \cdot psi$$

Shear stress in female threads, including seismic in the Z-direction

$$\tau_{thread1\,SD} := \sqrt{\tau_{thread1\,SDx}^{2} + \tau_{thread1\,SDy}^{2} + \tau_{thread1\,SDz}^{2}} = 488.625 \cdot psi$$

Combined Shear stress in female threads, including seismic

$$SF_{thread1\,SD} := \frac{\sigma_{yield1.2}}{\sqrt{3} \cdot \tau_{thread1\,SD}} = 41.355$$

Seismic Factor of Safety for female threads

1.3 Recommended Torque:

$$F_{bolt\_yield1} := \sigma_{allow1bolt} \cdot A_{m1} = 593.798 \cdot lbf$$

Maximum force allowed on SS bolt

$$F_{thread\_yield1} := \frac{\sigma_{yield1.2}}{\sqrt{3}} \cdot A_{s1} = 565.395 \cdot lbf$$

Maximum force allowed on female threads

$$K_1 := 0.20$$

Friction factor for threads, per EDSS table 1.2-1, section 1.2.4.2, rev 1 (Female threads = Stainless Steel, Male threads = Stainless Steel, Friction = Lubricated - Silver Plated)

$$T_{1.3} := K_1 \cdot D_{n1} \cdot F_{bolt\_yield1} \cdot (0.6) = 13.539 \cdot in \cdot lbf$$

Recommended torque for bolt (60% of material yield strength used, per EDSS section 1.2). The TIM Boat has SS threaded inserts, therefore the bolt will actually yield first.

2. TIM Mounting Frame (TIM mounting rail) to TIM Mounting Rail (top left mounting rail)

Given:

$W_2 := W_{spect} = 18.5\cdot lbf$ Dead weight of Spectrometer Assembly

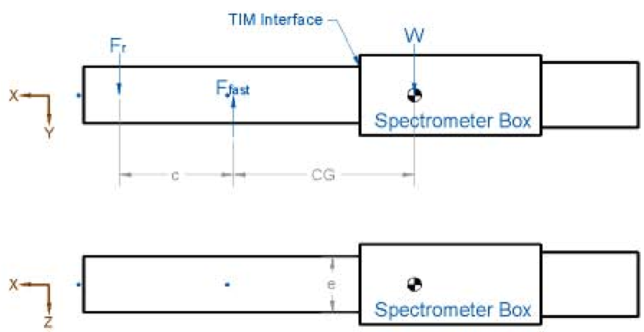
$CG_2 := CG_{spect} - 0.375in = 11.271\cdot in$ CG of Spectrometer Assembly

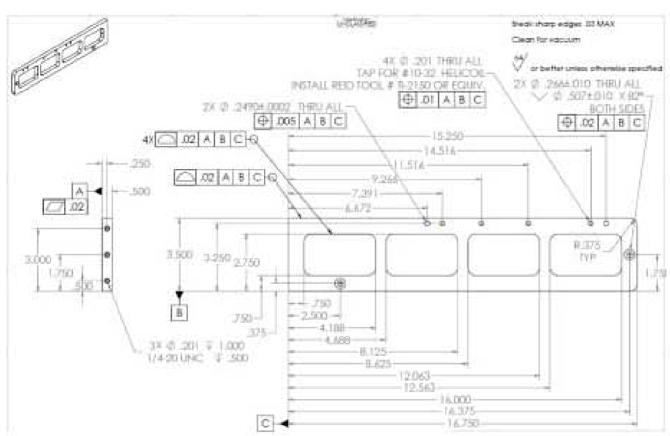
$d_{2c} := 7.125in$ Distance between fasteners (x-direction)

$d_{2e} := 3.5in$ Distance between fasteners (z-direction)

$n_{t2} := 2$ Number of fasteners used for tension only

$n_{tot2} := 8$ Total number of fasteners





2.1 10-32 Fasteners:

$D_{n2} := 0.19in$ Nominal diameter of 10-32

$TPI_2 := \frac{32}{in}$

$D_{m2} := D_{n2} - \frac{1}{TPI_2} = 0.159 \cdot in$ Mean diameter of fastener

$A_{m2} := \frac{\pi \cdot (D_{m2})^2}{4} = 0.02 \cdot in^2$ Area of fastener

$T_2 := \frac{W_2 \cdot CG_2}{d_{2c} \cdot n_{t2}} = 14.633 \cdot lbf$ Tensile force acting on fastener

$\sigma_2 := \frac{T_2}{A_{m2}} = 739.268 \cdot psi$ Tensile stress in fastener

$\tau_2 := \frac{W_2}{n_{tot2} \cdot A_{m2}} = 116.833 \cdot psi$ Shear stress in fastener

$\sigma_{vm2} := \sqrt{{\sigma_2}^2 + 3 \cdot (\tau_2)^2} = 766.464 \cdot psi$ Von Mises stresses in fastener

$\sigma_{allow2bolt} := \sigma_{y\_SS\_bolt} = 3 \times 10^4 \cdot psi$ Yield strength of SS SHCS

$SF_2 := \frac{\sigma_{allow2bolt}}{\sigma_{vm2}} = 39.141$ Static Factor of Safety for Fastener

2.1a Seismic Analysis:

$SD_{x2} := SD_x \cdot W_2 = 5.55 \cdot lbf$

$SD_{y2} := SD_y \cdot W_2 = 3.7 \cdot lbf$

$SD_{z2} := SD_z \cdot W_2 = 5.55 \cdot lbf$

X-Dir:

$\tau_{2SDx} := \frac{SD_{x2}}{n_{tot2} \cdot A_{m2}} = 35.05 \cdot psi$ Shear stress in fastener, including seismic

$\sigma_{vm2SDx} := \sqrt{3 \cdot (\tau_{2SDx})^2} = 60.708 \cdot psi$ Von Mises stresses in fastener, including seismic in the X-direction

Y-Dir:

$T_{2SDy} := \frac{(W_2 + SD_{y2}) \cdot CG_2}{d_{2c} \cdot n_{t2}} = 17.559 \cdot lbf$ Tensile force acting on fastener, including seismic

$\sigma_{2SDy} := \frac{T_{2SDy}}{A_{m2}} = 887.122 \cdot psi$ Tensile stress in fastener, including seismic

$\tau_{2SDy} := \frac{(W_2 + SD_{y2})}{n_{tot2} \cdot A_{m2}} = 140.199 \cdot psi$ Shear stress in fastener, including seismic

$\sigma_{vm2SDy} := \sqrt{\sigma_{2SDy}^2 + 3 \cdot (\tau_{2SDy})^2} = 919.757 \cdot psi$ Von Mises stresses in fastener, including seismic in the Y-direction

Z-Dir:

$T_{2SDz} := \frac{SD_{z2} \cdot CG_2}{d_{2c} \cdot \left(\frac{n_{tot2}}{2}\right)} = 2.195 \cdot lbf$ Tensile force acting on fastener, including seismic

$\sigma_{2SDz} := \frac{T_{2SDz}}{A_{m2}} = 110.89 \cdot psi$ Tensile stress in fastener, including seismic

$\sigma_{vm2SDz} := \sqrt{\sigma_{2SDz}^2} = 110.89 \cdot psi$ Von Mises stresses in fastener, including seismic in the Z-direction

$\sigma_{vm2SD} := \sqrt{\sigma_{vm2SDx}^2 + \sigma_{vm2SDy}^2 + \sigma_{vm2SDz}^2} = 928.404 \cdot psi$ Von Mises stresses in fastener, including seismic

$SF_{2SD} := \frac{\sigma_{allow2bolt}}{\sigma_{vm2SD}} = 32.314$ Seismic Factor of Safety for Fastener

2.2 Thread Shear in the Tapped Holes:

$\sigma_{yield2.2} := \sigma_{y\_Al6061T6} = 3.5 \times 10^4 \cdot psi$ Yield strength of Aluminum

$D_{n2} = 0.19 \cdot in$ Information on threaded inserts is unknown, assume no inserts (this is a conservative assumption)

$Le_2 := \frac{3}{32} in = 0.094 \cdot in$ Length of engagement unknown, assume 3 threads

$A_{s2} := \frac{\pi \cdot D_{n2} \cdot Le_2}{2} = 0.028 \cdot in^2$ Shear area of female threads

$\tau_{thread2} := \frac{T_2}{A_{s2}} = 522.967 \cdot psi$ Shear stress in female threads

$SF_{thread2} := \frac{\sigma_{yield2.2}}{\sqrt{3} \cdot \tau_{thread2}} = 38.64$ Factor of Safety for Female Threads

2.2a Seismic Analysis:

X-Dir:

$$\tau_{thread2SDx} := \frac{SD_{x2}}{n_{tot2} \cdot A_{s2}} = 24.795 \cdot psi$$

Shear stress in female threads, including seismic in the X-direction

Y-Dir:

$$\tau_{thread2SDy} := \frac{T_{2SDy}}{A_{s2}} = 627.561 \cdot psi$$

Shear stress in female threads, including seismic in the Y-direction

Z-Dir:

$$\tau_{thread2SDz} := \frac{T_{2SDz}}{A_{s2}} = 78.445 \cdot psi$$

Shear stress in female threads, including seismic in the Z-direction

$$\tau_{thread2SD} := \sqrt{\tau_{thread2SDx}^2 + \tau_{thread2SDy}^2 + \tau_{thread2SDz}^2} = 632.93 \cdot psi$$

Combined Shear stress in female threads, including seismic

$$SF_{thread2SD} := \frac{\sigma_{yield2.2}}{\sqrt{3} \cdot \tau_{thread2SD}} = 31.927$$

Seismic Factor of Safety for female threads

2.3 Recommended Torque:

$$F_{bolt\_yield2} := \sigma_{allow2bolt} \cdot A_{m2} = 593.798 \cdot lbf$$

Maximum force allowed on SS bolt

$$F_{thread\_yield2} := \frac{\sigma_{yield2.2}}{\sqrt{3}} \cdot A_{s2} = 565.395 \cdot lbf$$

Maximum force allowed on female threads

$$K_2 := 0.20$$

Friction factor for threads, per EDSS table 1.2-1, section 1.2.4.2, rev 1 (Female threads = Stainless Steel, Male threads = Stainless Steel, Friction = Lubricated - Silver Plated)

$$T_{2.3} := K_2 \cdot D_{n2} \cdot F_{bolt\_yield2} \cdot (0.6) = 13.539 \cdot in \cdot lbf$$

Recommended torque for bolt (60% of material yield strength used, per EDSS section 1.2). The TIM Mounting Frame has SS threaded inserts, therefore the bolt will actually yield first.

3. TIM Mounting Frame (TIM mounting rail) to TIM Mounting Plate

Given:

$W_3 := W_{spect} = 18.5 \cdot lbf$ Dead weight of Spectrometer Assembly

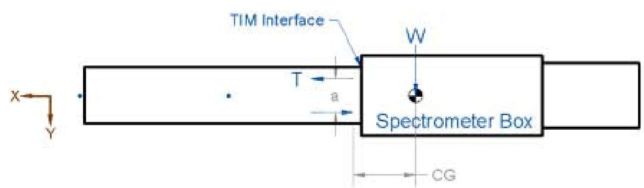
$CG_3 := CG_{spect} - 7.391in - .375in = 3.88 \cdot in$ CG of Spectrometer Assembly

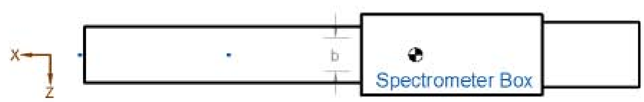
$d_{3a} := 4in$ Distance between fasteners (x-direction)

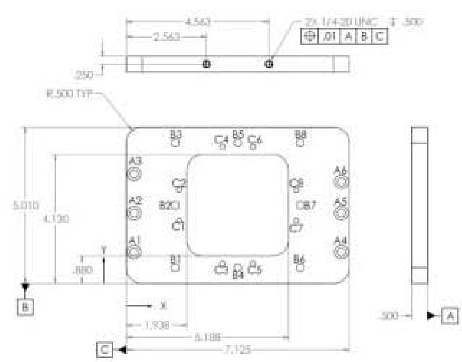
$d_{3b} := 4in$ Distance between fasteners (z-direction)

$n_{t3} := 2$ Number of fasteners used for tension only

$n_{tot3} := 6$ Total number of fasteners







3.1 1/4-20 Fasteners:

$D_{n3} := 0.25in$ Nominal diameter of 1/4-20

$TPI_3 := \frac{20}{in}$

$D_{m3} := D_{n3} - \frac{1}{TPI_3} = 0.2 \cdot in$ Mean diameter of fastener

$A_{m3} := \frac{\pi \cdot (D_{m3})^2}{4} = 0.031 \cdot in^2$ Area of fastener

$T_3 := \frac{W_3 \cdot CG_3}{d_{3a} \cdot n_{t3}} = 8.973 \cdot lbf$ Tensile force acting on fastener

$\sigma_3 := \frac{T_3}{A_{m3}} = 285.604 \cdot psi$ Tensile stress in fastener

$\tau_3 := \frac{W_3}{n_{tot3} \cdot A_{m3}} = 98.146 \cdot psi$ Shear stress in fastener

$\sigma_{vm3} := \sqrt{\sigma_3^{\,2} + 3 \cdot (\tau_3)^2} = 332.366 \cdot psi$ Von Mises stresses in fastener

$\sigma_{allow3bolt} := \sigma_{y\_SS\_bolt} = 3 \times 10^4 \cdot psi$ Yield strength of SS SHCS

$SF_3 := \frac{\sigma_{allow3bolt}}{\sigma_{vm3}} = 90.262$ Static Factor of Safety for Fastener

3.1a Seismic Analysis:

$SD_{x3} := SD_x \cdot W_3 = 5.55 \cdot lbf$

$SD_{y3} := SD_y \cdot W_3 = 3.7 \cdot lbf$

$SD_{z3} := SD_z \cdot W_3 = 5.55 \cdot lbf$

X-Dir:

$\sigma_{3SDx} := \frac{SD_{x3}}{n_{tot3} \cdot A_{m3}} = 29.444 \cdot psi$ Tensile stress in fastener, including seismic

$\sigma_{vm3SDx} := \sigma_{3SDx} = 29.444 \cdot psi$ Von Mises stresses in fastener, including seismic in the X-direction

Y-Dir:

$T_{3SDy} := \frac{(W_3 + SD_{y3}) \cdot CG_3}{d_{3a} \cdot n_{t3}} = 10.767 \cdot lbf$ Tensile force acting on fastener, including seismic

$\sigma_{3SDy} := \frac{T_{3SDy}}{A_{m3}} = 342.724 \cdot psi$ Tensile stress in fastener, including seismic

$\tau_{3SDy} := \frac{(W_3 + SD_{y3})}{n_{tot3} \cdot A_{m3}} = 117.775 \cdot psi$ Shear stress in fastener, including seismic

$\sigma_{vm3SDy} := \sqrt{\sigma_{3SDy}^2 + 3 \cdot (\tau_{3SDy})^2} = 398.839 \cdot psi$ Von Mises stresses in fastener, including seismic in the Y-direction

Z-Dir:

$T_{3SDz} := \frac{SD_{z3} \cdot CG_3}{d_{3b} \cdot \left(\frac{n_{tot3}}{2}\right)} = 1.795 \cdot lbf$ Tensile force acting on fastener, including seismic

$\sigma_{3SDz} := \frac{T_{3SDz}}{A_{m3}} = 57.121 \cdot psi$ Tensile stress in fastener, including seismic

$\tau_{3SDz} := \frac{SD_{z3}}{n_{tot3} \cdot A_{m3}} = 29.444 \cdot psi$ Shear stress in fastener, including seismic

$\sigma_{vm3SDz} := \sqrt{\sigma_{3SDz}^2 + 3(\tau_{3SDz})^2} = 76.574 \cdot psi$ Von Mises stresses in fastener, including seismic in the Z-direction

$\sigma_{vm3SD} := \sqrt{\sigma_{vm3SDx}^2 + \sigma_{vm3SDy}^2 + \sigma_{vm3SDz}^2} = 407.189 \cdot psi$ Von Mises stresses in fastener, including seismic

$SF_{3SD} := \frac{\sigma_{allow3bolt}}{\sigma_{vm3SD}} = 73.676$ Seismic Factor of Safety for Fastener

3.2 Thread Shear in the Tapped Holes:

$\sigma_{yield3.2} := \sigma_{y\_Al6061T6} = 3.5 \times 10^4 \cdot psi$ Yield strength of Aluminum

$D_{n3} = 0.25 \cdot in$ Nominal Diameter

$Le_3 := 0.25in$ Length of engagement

$A_{s3} := \frac{\pi \cdot D_{n3} \cdot Le_3}{2} = 0.098 \cdot in^2$ Shear area of female threads

$\tau_{thread3} := \frac{T_3}{A_{s3}} = 91.393 \cdot psi$ Shear stress in female threads

$SF_{thread3} := \dfrac{\sigma_{yield3.2}}{\sqrt{3} \cdot \tau_{thread3}} = 221.103$ Factor of Safety for Female Threads

3.2a Seismic Analysis:

X-Dir:

$\tau_{thread3SDx} := \dfrac{SD_{x3}}{n_{tot3} \cdot A_{s3}} = 9.422 \cdot psi$ Shear stress in female threads, including seismic in the X-direction

Y-Dir:

$\tau_{thread3SDy} := \dfrac{T_{3SDy}}{A_{s3}} = 109.672 \cdot psi$ Shear stress in female threads, including seismic in the Y-direction

Z-Dir:

$\tau_{thread3SDz} := \dfrac{T_{3SDz}}{A_{s3}} = 18.279 \cdot psi$ Shear stress in female threads, including seismic in the Z-direction

$\tau_{thread3SD} := \sqrt{\tau_{thread3SDx}^{\;2} + \tau_{thread3SDy}^{\;2} + \tau_{thread3SDz}^{\;2}} = 111.583 \cdot psi$ Combined Shear stress in female threads, including seismic

$SF_{thread3SD} := \dfrac{\sigma_{yield3.2}}{\sqrt{3} \cdot \tau_{thread3SD}} = 181.096$ Seismic Factor of Safety for female threads

3.3 Recommended Torque:

$F_{bolt\_yield3} := \sigma_{allow3bolt} \cdot A_{m3} = 942.478 \cdot lbf$ Maximum force allowed on SS bolt

$F_{thread\_yield3} := \dfrac{\sigma_{yield3.2}}{\sqrt{3}} \cdot A_{s3} = 1.984 \times 10^{3} \cdot lbf$ Maximum force allowed on female threads

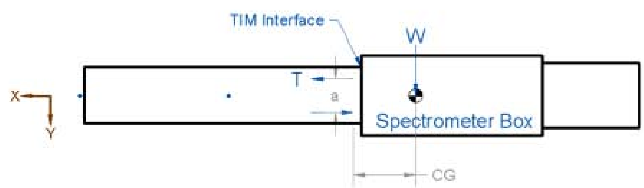
$K_3 := 0.20$ Friction factor for threads, per EDSS table 1.2-1, section 1.2.4.2, rev 1 (Female threads = Aluminum, Male threads = Stainless Steel, Friction = Lubricated - Silver Plated)

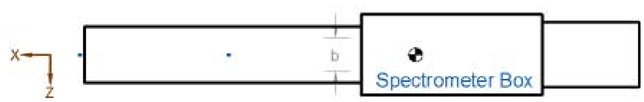
$T_{3.3} := K_3 \cdot D_{n3} \cdot F_{bolt\_yield3} \cdot (0.6) = 28.274 \cdot in \cdot lbf$ Recommended torque for bolt (60% of material yield strength used, per EDSS section 1.2)

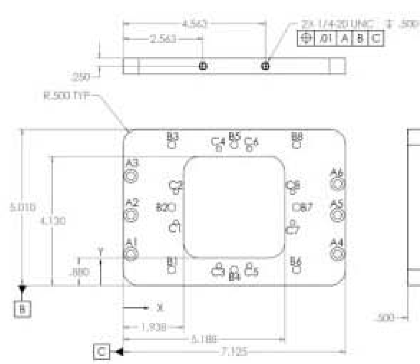
4. TIM Mounting Plate to HOPG Mounting Plate (rear lead shield)

Given:

$W_4 := W_{spect} = 18.5 \cdot lbf$	Dead weight of Spectrometer Assembly
$CG_4 := CG_{spect} - .375in - 7.391in - 0.5in = 3.38 \cdot in$	CG of Spectrometer Assembly
$d_{4a} := 4in$	Distance between fasteners (x-direction)
$d_{4b} := 4in$	Distance between fasteners (z-direction)
$n_{t4} := 2$	Number of fasteners used for tension only
$n_{tot4} := 6$	Total number of fasteners







4.1 1/4-20 Fasteners:

$D_{n4} := 0.25in$ Nominal diameter of 1/4-20

$TPI_4 := \frac{20}{in}$

$D_{m4} := D_{n4} - \frac{1}{TPI_4} = 0.2 \cdot in$ Mean diameter of fastener

$A_{m4} := \frac{\pi \cdot (D_{m4})^2}{4} = 0.031 \cdot in^2$ Area of fastener

$T_4 := \frac{W_4 \cdot CG_4}{d_{4a} \cdot n_{t4}} = 7.816 \cdot lbf$ Tensile force acting on fastener

$\sigma_4 := \frac{T_4}{A_{m4}} = 248.799 \cdot psi$ Tensile stress in fastener

$\tau_4 := \frac{W_4}{n_{tot4} \cdot A_{m4}} = 98.146 \cdot psi$ Shear stress in fastener

$\sigma_{vm4} := \sqrt{\sigma_4^{\ 2} + 3 \cdot (\tau_4)^2} = 301.328 \cdot psi$ Von Mises stresses in fastener

$\sigma_{allow4bolt} := \sigma_{y\_SS\_bolt} = 3 \times 10^4 \cdot psi$ Yield strength of SS SHCS

$SF_4 := \frac{\sigma_{allow4bolt}}{\sigma_{vm4}} = 99.559$ Static Factor of Safety for Fastener

4.1a Seismic Analysis:

$SD_{x4} := SD_x \cdot W_4 = 5.55 \cdot lbf$

$SD_{y4} := SD_y \cdot W_4 = 3.7 \cdot lbf$

$SD_{z4} := SD_z \cdot W_4 = 5.55 \cdot lbf$

X-Dir:

$\sigma_{4SDx} := \frac{SD_{x4}}{n_{tot4} \cdot A_{m4}} = 29.444 \cdot psi$ Tensile stress in fastener, including seismic

$\sigma_{vm4SDx} := \sigma_{4SDx} = 29.444 \cdot psi$ Von Mises stresses in fastener, including seismic in the X-direction

Y-Dir:

$$T_{4SDy} := \frac{(W_4 + SD_{y4}) \cdot CG_4}{d_{4a} \cdot n_{t4}} = 9.38 \cdot lbf$$ Tensile force acting on fastener, including seismic

$$\sigma_{4SDy} := \frac{T_{4SDy}}{A_{m4}} = 298.559 \cdot psi$$ Tensile stress in fastener, including seismic

$$\tau_{4SDy} := \frac{(W_4 + SD_{y4})}{n_{tot4} \cdot A_{m4}} = 117.775 \cdot psi$$ Shear stress in fastener, including seismic

$$\sigma_{vm4SDy} := \sqrt{\sigma_{4SDy}{}^2 + 3 \cdot (\tau_{4SDy})^2} = 361.594 \cdot psi$$ Von Mises stresses in fastener, including seismic in the Y-direction

Z-Dir:

$$T_{4SDz} := \frac{SD_{z4} \cdot CG_4}{d_{4b} \cdot \left(\frac{n_{tot4}}{2}\right)} = 1.563 \cdot lbf$$ Tensile force acting on fastener, including seismic

$$\sigma_{4SDz} := \frac{T_{4SDz}}{A_{m4}} = 49.76 \cdot psi$$ Tensile stress in fastener, including seismic

$$\tau_{4SDz} := \frac{SD_{z4}}{n_{tot4} \cdot A_{m4}} = 29.444 \cdot psi$$ Shear stress in fastener, including seismic

$$\sigma_{vm4SDz} := \sqrt{\sigma_{4SDz}{}^2 + 3(\tau_{4SDz})^2} = 71.252 \cdot psi$$ Von Mises stresses in fastener, including seismic in the Z-direction

$$\sigma_{vm4SD} := \sqrt{\sigma_{vm4SDx}{}^2 + \sigma_{vm4SDy}{}^2 + \sigma_{vm4SDz}{}^2} = 369.721 \cdot psi$$ Von Mises stresses in fastener, including seismic

$$SF_{4SD} := \frac{\sigma_{allow4bolt}}{\sigma_{vm4SD}} = 81.142$$ Seismic Factor of Safety for Fastener

4.2 Thread Shear in the Tapped Holes:

$$\sigma_{yield4.2} := \sigma_{y\_Al6061T6} = 3.5 \times 10^4 \cdot psi$$ Yield strength of Aluminum

$$D_{n4} = 0.25 \cdot in$$ Nominal Diameter

$$Le_4 := 0.25in$$ Length of engagement

$$A_{s4} := \frac{\pi \cdot D_{n4} \cdot Le_4}{2} = 0.098 \cdot in^2$$ Shear area of female threads

$$\tau_{thread4} := \frac{T_4}{A_{s4}} = 79.616 \cdot psi$$ Shear stress in female threads

$SF_{thread4} := \frac{\sigma_{yield4.2}}{\sqrt{3} \cdot \tau_{thread4}} = 253.81$ Factor of Safety for Female Threads

4.2a Seismic Analysis:

X-Dir:

$\tau_{thread4SDx} := \frac{SD_{x4}}{n_{tot4} \cdot A_{s4}} = 9.422 \cdot psi$ Shear stress in female threads, including seismic in the X-direction

Y-Dir:

$\tau_{thread4SDy} := \frac{T_{4SDy}}{A_{s4}} = 95.539 \cdot psi$ Shear stress in female threads, including seismic in the Y-direction

Z-Dir:

$\tau_{thread4SDz} := \frac{T_{4SDz}}{A_{s4}} = 15.923 \cdot psi$ Shear stress in female threads, including seismic in the Z-direction

$\tau_{thread4SD} := \sqrt{\tau_{thread4SDx}^2 + \tau_{thread4SDy}^2 + \tau_{thread4SDz}^2} = 97.314 \cdot psi$ Combined Shear stress in female threads, including seismic

$SF_{thread4SD} := \frac{\sigma_{yield4.2}}{\sqrt{3} \cdot \tau_{thread4SD}} = 207.65$ Seismic Factor of Safety for female threads

4.3 Recommended Torque:

$F_{bolt\_yield4} := \sigma_{allow4bolt} \cdot A_{m4} = 942.478 \cdot lbf$ Maximum force allowed on SS bolt

$F_{thread\_yield4} := \frac{\sigma_{yield4.2}}{\sqrt{3}} \cdot A_{s4} = 1.984 \times 10^3 \cdot lbf$ Maximum force allowed on female threads

$K_4 := 0.20$ Friction factor for threads, per EDSS table 1.2-1, section 1.2.4.2, rev 1 (Female threads = Aluminum, Male threads = Stainless Steel, Friction = Lubricated - Silver Plated)

$T_{4.3} := K_4 \cdot D_{n4} \cdot F_{bolt\_yield4} \cdot (0.6) = 28.274 \cdot in \cdot lbf$ Recommended torque for bolt (60% of material yield strength used, per EDSS section 1.2)

5. HOPG Mounting Plate (rear lead shield) to Spectrometer Assembly Side Plates (right rear side plate & left rear side plate)

Given:

$W_5 := W_{spect} = 18.5 \cdot lbf$ Dead weight of Spectrometer Assembly

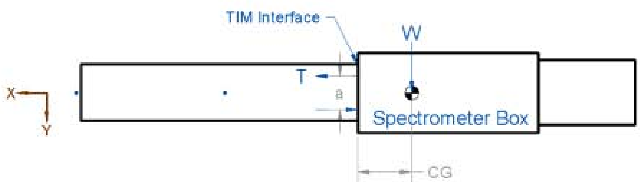
$CG_5 := CG_{spect} - 7.391in - .875in - .75in = 2.63 \cdot in$ CG of Spectrometer Assembly

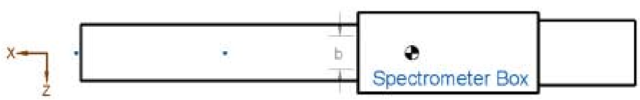
$d_{5a} := 2.542in$ Distance between fasteners (x-direction)

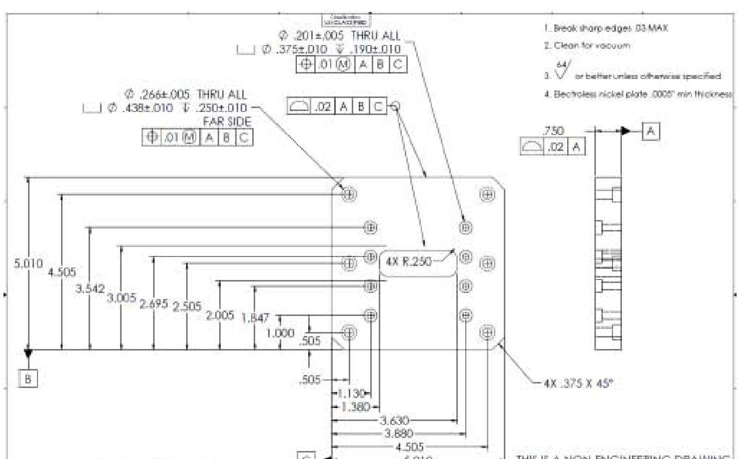
$d_{5b} := 2.75in$ Distance between fasteners (z-direction)

$n_{t5} := 2$ Number of fasteners used for tension only

$n_{tot5} := 8$ Total number of fasteners







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5.1 10-32 Fasteners:

$D_{n5} := 0.19\text{in}$ — Nominal diameter of 10-32

$TPI_5 := \frac{32}{\text{in}}$

$D_{m5} := D_{n5} - \frac{1}{TPI_5} = 0.159 \cdot \text{in}$ — Mean diameter of fastener

$A_{m5} := \frac{\pi \cdot (D_{m5})^2}{4} = 0.02 \cdot \text{in}^2$ — Area of fastener

$T_5 := \frac{W_5 \cdot CG_5}{d_{5a} \cdot n_{t5}} = 9.57 \cdot \text{lbf}$ — Tensile force acting on fastener

$\sigma_5 := \frac{T_5}{A_{m5}} = 483.509 \cdot \text{psi}$ — Tensile stress in fastener

$\tau_5 := \frac{W_5}{n_{tot5} \cdot A_{m5}} = 116.833 \cdot \text{psi}$ — Shear stress in fastener

$\sigma_{vm5} := \sqrt{\sigma_5^{\,2} + 3 \cdot (\tau_5)^2} = 524.148 \cdot \text{psi}$ — Von Mises stresses in fastener

$\sigma_{allow5bolt} := \sigma_{y\_SS\_bolt} = 3 \times 10^4 \cdot \text{psi}$ — Yield strength of SS SHCS

$SF_5 := \frac{\sigma_{allow5bolt}}{\sigma_{vm5}} = 57.236$ — Static Factor of Safety for Fastener

5.1a Seismic Analysis:

$SD_{x5} := SD_x \cdot W_5 = 5.55 \cdot \text{lbf}$

$SD_{y5} := SD_y \cdot W_5 = 3.7 \cdot \text{lbf}$

$SD_{z5} := SD_z \cdot W_5 = 5.55 \cdot \text{lbf}$

X-Dir:

$\sigma_{5SDx} := \frac{SD_{x5}}{n_{tot5} \cdot A_{m5}} = 35.05 \cdot \text{psi}$ — Tensile stress in fastener, including seismic

$\sigma_{vm5SDx} := \sigma_{5SDx} = 35.05 \cdot \text{psi}$ — Von Mises stresses in fastener, including seismic in the X-direction

Y-Dir:

$$T_{5SDy} := \frac{(W_5 + SD_{y5}) \cdot CG_5}{d_{5a} \cdot n_{t5}} = 11.484 \cdot lbf$$ Tensile force acting on fastener, including seismic

$$\sigma_{5SDy} := \frac{T_{5SDy}}{A_{m5}} = 580.211 \cdot psi$$ Tensile stress in fastener, including seismic

$$\tau_{5SDy} := \frac{(W_5 + SD_{y5})}{n_{tot5} \cdot A_{m5}} = 140.199 \cdot psi$$ Shear stress in fastener, including seismic

$$\sigma_{vm5SDy} := \sqrt{\sigma_{5SDy}^2 + 3 \cdot (\tau_{5SDy})^2} = 628.977 \cdot psi$$ Von Mises stresses in fastener, including seismic in the Y-direction

Z-Dir:

$$T_{5SDz} := \frac{SD_{z5} \cdot CG_5}{d_{5b} \cdot \left(\frac{n_{tot5}}{2}\right)} = 1.327 \cdot lbf$$ Tensile force acting on fastener, including seismic

$$\sigma_{5SDz} := \frac{T_{5SDz}}{A_{m5}} = 67.041 \cdot psi$$ Tensile stress in fastener, including seismic

$$\tau_{5SDz} := \frac{SD_{z5}}{n_{tot5} \cdot A_{m5}} = 35.05 \cdot psi$$ Shear stress in fastener, including seismic

$$\sigma_{vm5SDz} := \sqrt{\sigma_{5SDz}^2 + 3(\tau_{5SDz})^2} = 90.443 \cdot psi$$ Von Mises stresses in fastener, including seismic in the Z-direction

$$\sigma_{vm5SD} := \sqrt{\sigma_{vm5SDx}^2 + \sigma_{vm5SDy}^2 + \sigma_{vm5SDz}^2} = 636.412 \cdot psi$$ Von Mises stresses in fastener, including seismic

$$SF_{5SD} := \frac{\sigma_{allow5bolt}}{\sigma_{vm5SD}} = 47.139$$ Seismic Factor of Safety for Fastener

5.2 Thread Shear in the Tapped Holes:

$$\sigma_{yield5.2} := \sigma_{y\_Al6061T6} = 3.5 \times 10^4 \cdot psi$$ Yield strength of Aluminum

$$D_{n5ins} := 0.21 in$$ Diameter of Heli-Coil hole (assume KLI-66521 threaded insert installed per manufacturers rec.)

$$Le_{5ins} := 0.31 in$$ Length of engagement

$$A_{s5ins} := \frac{\pi \cdot D_{n5ins} \cdot Le_{5ins}}{2} = 0.102 \cdot in^2$$ Shear area of female threads

$$\sigma_{allow5ins} := \frac{\sigma_{y\_Al6061T6}}{\sqrt{3}} = 2.021 \times 10^4 \cdot psi$$ Allowable stress in female threadss (0.577 yield)

$T_{5max\_ins} := A_{s5ins} \cdot \sigma_{allow5ins} = 2.066 \times 10^{3} \cdot lbf$ Max allowable tensile force on insert

$T_5 = 9.57 \cdot lbf \quad < T_{5max\_ins}$

$\tau_{thread5} := \frac{T_5}{A_{s5ins}} = 93.588 \cdot psi$ Shear stress in female threads

$SF_{thread5} := \frac{\sigma_{yield5.2}}{\sqrt{3} \cdot \tau_{thread5}} = 215.917$ Factor of Safety for Female Threads

5.2a Seismic Analysis:

X-Dir:

$\tau_{thread5SDx} := \frac{SD_{x5}}{n_{tot5} \cdot A_{s5ins}} = 6.784 \cdot psi$ Shear stress in female threads, including seismic in the X-direction

Y-Dir:

$\tau_{thread5SDy} := \frac{T_{5SDy}}{A_{s5ins}} = 112.306 \cdot psi$ Shear stress in female threads, including seismic in the Y-direction

Z-Dir:

$\tau_{thread5SDz} := \frac{T_{5SDz}}{A_{s5ins}} = 12.976 \cdot psi$ Shear stress in female threads, including seismic in the Z-direction

$\tau_{thread5SD} := \sqrt{\tau_{thread5SDx}^2 + \tau_{thread5SDy}^2 + \tau_{thread5SDz}^2} = 113.256 \cdot psi$ Combined Shear stress in female threads, including seismic

$SF_{thread5SD} := \frac{\sigma_{yield5.2}}{\sqrt{3} \cdot \tau_{thread5SD}} = 178.42$ Seismic Factor of Safety for female threads

5.3 Recommended Torque:

$F_{bolt\_yield5} := \sigma_{allow5bolt} \cdot A_{m5} = 593.798 \cdot lbf$ Maximum force allowed on SS bolt

$F_{thread\_yield5} := \frac{\sigma_{yield5.2}}{\sqrt{3}} \cdot A_{s5ins} = 2.066 \times 10^{3} \cdot lbf$ Maximum force allowed on female threads

$K_5 := 0.20$ Friction factor for threads, per EDSS table 1.2-1, section 1.2.4.2, rev 1 (Female threads = Stainless Steel, Male threads = Stainless Steel, Friction = Lubricated - Silver Plated)

$T_{5.3} := K_5 \cdot D_{n5} \cdot F_{bolt\_yield5} \cdot (0.6) = 13.539 \cdot in \cdot lbf$ Recommended torque for bolt (60% of material yield strength used, per EDSS section 1.2)

Appendix B – DC HOPG Operations Procedure

Date: Wed, 29 Apr 2009 14:12:14 -0400
From: Dino Mastrosimone <dmas@lle.rochester.edu>
Organization: U of R - Laboratory for laser Energetics
To: Charles Sorce <csor@lle.rochester.edu>, Bob Heeter <heeter1@llnl.gov>,
"Allen J. Elsholz" <elsholz1@llnl.gov>
CC: Greg Pien <pien@lle.rochester.edu>, Milton Shoup <shoup@lle.rochester.edu>,
Keith Thorp <thorp@lle.rochester.edu>,
Sam Morse <smor@lle.rochester.edu>
Subject: Use of DCHOPG with Lifting Handle for shot operations on 30 April 2009

LLNL Personnel,

This letter is to inform LLNL that LLE is taking responsibility to authorize the use of the new DCHOPG handle as shown in the attached Operating Procedure. The handle had been designed and inspected by Craig Robillard, Mechanical Engineer and Milt Shoup, Chief Mechanical Engineer/ Mechanical Safety Officer, respectively.

Please contact me with any questions or concerns you may have regarding the assembly.

Regards,

Dino Mastrosimone

6-2.8 Dual Channel (DCHOPG)

Diagnostic Description

The Dual Channel HOPG (DCHOPG) is a TIM based diagnostic that contains a pair of X-ray diffraction crystals for energies between 7.1 keV to 13.3 keV. The diagnostic does not require power, chilled water, timing or communications. All materials are vacuum compatible and the proposed alignment method shall utilize a ruby tipped pointer mounted at the nose of the diagnostic.

Handling Instructions

1. Weight of the assembly is ~ 54 pounds.
   - Single operator lifting of the diagnostic into the TIM without crane assistance is prohibited.
   - The handle, which stays with the diagnostic, resides within the diagnostic space envelope.
2. The Center of gravity of this diagnostic is ~ 12.825 inches in front of the tooling balls location. Care must be taken when installation and removal is required.

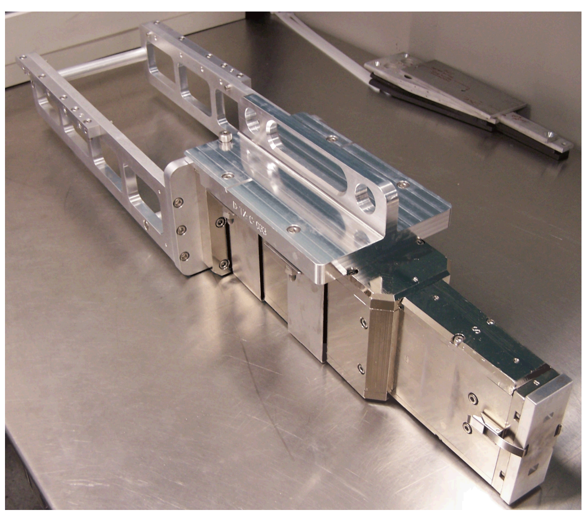


Figure 1: Dual Channel HOPG (DC HOPG)

6-2.8.1 DC HOPG Pre-Installation Inspection

Intent

This procedure is to be used to inspect the DC HOPG prior to TIM installation.

Prerequisites

Confirm that the following conditions have been met:

1)	DC HOPG has been requested on an upcoming RID, and all required configuration information and hardware are available.	❑
2)	A minimum of two image plate film packs are available to support the shot operations for the campaign	❑

Procedure

1)	Inspect the DC HOPG body. Ensure that it is fully assembled, complete with handle and that all fasteners are secure	❑
2)	Ensure that its captive TIM mounting screws are installed and serviceable	❑
3)	Ensure that the tooling balls are installed and serviceable	❑
4)	Verify that the blast shield film material is not ruptured	❑
4)	DC HOPG pre installation inspection is now complete. Report any deficiencies to the ESO	❑

6-2.8.2 DC HOPG TIM Installation

Intent

This procedure is to be used to install the DC HOPG in its assigned TIM and configure it for operation.

Prerequisites

Confirm that the following conditions have been met:

1) The DC HOPG is assembled and configured as per its SRF setup sheet, as described by the responsible PI. ❑
2) Previously used diagnostics and equipment have been removed from the TIM and the TIM is in Retracted-Vented-Door Open state. ❑
3) A 5/32" Allen wrench is required for DC HOPG TIM installation. ❑

Procedure

1) Hoist DC HOPG assembly into the appropriate TIM body location ❑
2) Align DC HOPG tooling balls with the TIM boat and lower them into place ❑

   NOTE: Do not release payload from overhead hoist until step #3 is complete
3) Fasten the ten (10) #10-32 SHCS into the TIM boat. Tighten bolts in a crisscross star pattern starting with the outer fasteners working inward ❑
4) Remove the diagnostic rigging and lifting ring from assembly ❑

6-2.8.3 DC HOPG TIM Alignment Procedure

Intent

This procedure is to be used to point the DC HOPG to its target chamber center.

Prerequisites

Confirm that the following conditions have been met:

1)	The DCHOPG has been installed in the assigned TIM	☐
2)	Pointer assembly is available	☐
3)	Target Chamber Center (TCC) is clear of targets or other obstructions	☐
4)	No tools are required operation	☐

Procedure

1)	Release the 2 Southco latches on the front of the instrument	☐
2)	Remove the blast shield	☐
3)	Inspect tooling balls & front surface for contamination or damage	☐
4)	Install pointer assembly over tooling balls and secure in place with Southco latches	☐
5)	Close TIM door and inform ESO that TIM is ready for pump down and alignment to TCC	☐
6)	Once alignment has been completed replace the blast shield for shot operations	☐

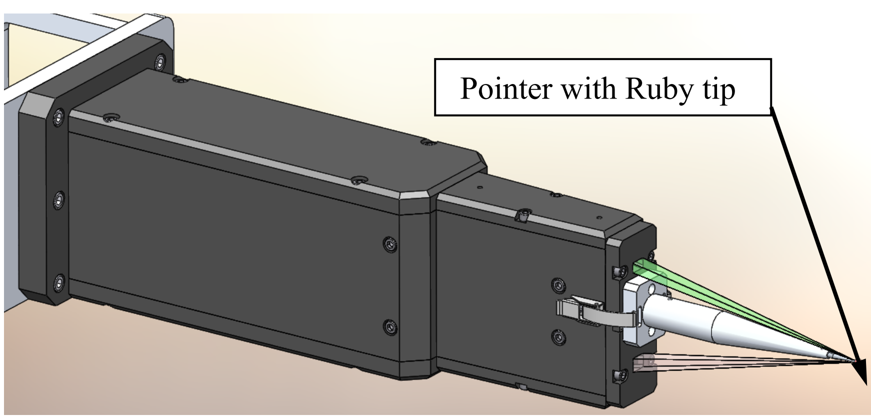


Figure 2: Pointer assembly installation

6-2.8.4 DC HOPG Shot Operations

Intent

This procedure is to be used to operate the DC HOPG on OMEGA EP target shots.

Prerequisites

Confirm that the following conditions have been met:

1)	The DC HOPG has been installed in its assigned TIM and pointed to its alignment coordinates, in accordance with "DC HOPG TIM Installation" (Procedure 6-2.8.2) and DC HOPG TIM Alignment Procedure" (Procedure 6-2.8.3)	☐
2)	Note: No tools are required for DC HOPG shot operations.	☐

Procedure

	Start with DC HOPG TIM in Retracted, Vented Door-Open state for Operating Procedures A) thru C)	☐

A) Start-up Conditions

1)	Obtain a fresh, unexposed image plate (IP) film pack, with the transport container, from the darkroom and take them to the DC HOPG TIM.	☐
2)	Loosen the cover retention thumb screw and open cartridge compartment	☐
3)	Insert the Image Plate film pack	☐
4)	Close the cover and re-tighten thumbscrew	☐
5)	Close the TIM door and report to the ESO that the IP film pack exchange has been completed. ** Loaded and ready for insertion **	☐
6)	Insert TIM to TCC in coordination with other diagnostics. DC HOPG is operationally passive during the shot. No operator intervention is needed during the shot.	☐

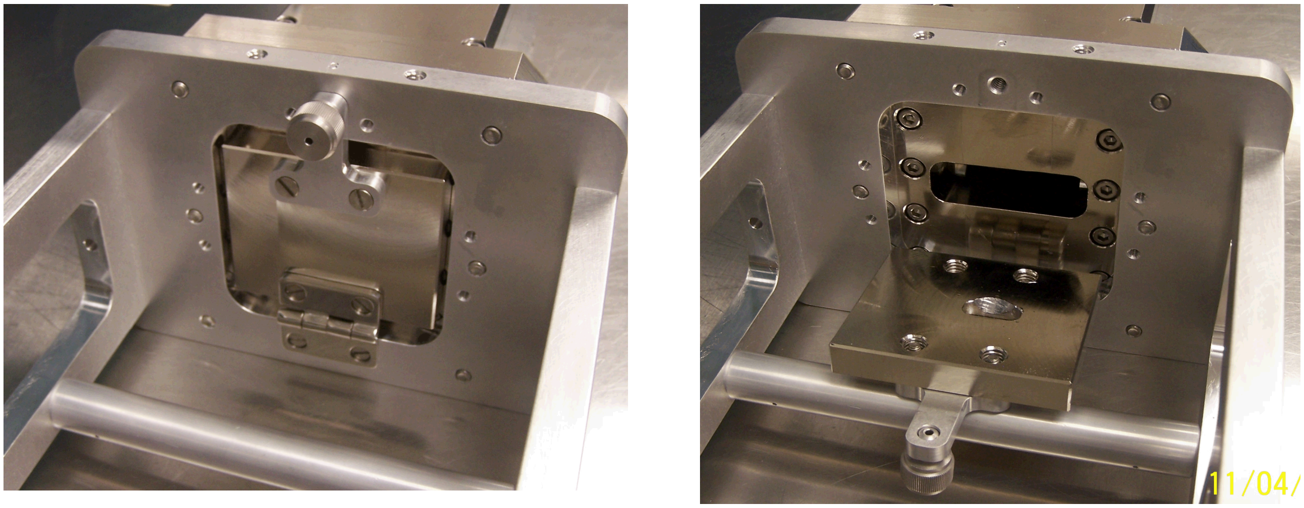


Figure 6: Image Plate (IP) cartridge location

B) Film Exchange (each shot cycle)

1) Obtain a fresh, unexposed image plate (IP) film pack, with the transport container, from the darkroom and take them to the DC HOPG TIM ☐
2) Loosen the cover retention thumb screw and open cartridge compartment ☐
3) Quickly remove the exposed IP and place in light tight container
   Caution: Material is extremely light sensitive ☐
4) Insert the new Image Plate film pack ☐
5) Close the cover and re-tighten thumbscrew ☐
6) Close the TIM door and report to the ESO that the IP film pack exchange has been completed. ** Loaded and ready for insertion ** ☐
7) Insert TIM to TCC in coordination with other diagnostics. DC HOPG is operationally passive during the shot. No operator intervention is needed during the shot. ☐
8) Take the exposed film pack located within the transport container to the darkroom for processing. ☐

6- 2.8.4 DC HOPG Shot Operations (con't)

C) Final Film Removal and TIM Securing

1)	Loosen the cover retention thumb screw and open cartridge compartment	❑
2)	Quickly remove the exposed IP and place in light tight container. ***Caution: Material is extremely light sensitive***	❑
3)	Close the cover and re-tighten thumbscrew	❑
4)	Close the TIM door and report to the ESO that the IP film pack exchange has been completed. ESO shall indicate TIM securing procedure	❑
5)	Take the exposed film pack located within the transport container to the darkroom for processing.	❑

** END OF PROCEDURE**

Appendix C – HOPG Lifting Handle

The HOPG Lifting Handle, shown in figure G-1. The intent is that LLE will use this handle to lift the HOPG assembly. Procedures for the use of the lift handle can be found in Appendix C – DC HOPG Operations Procedures.

The point of contact for this handle is: **Dino Mastrosimone**, dmas@lle.rochester.edu

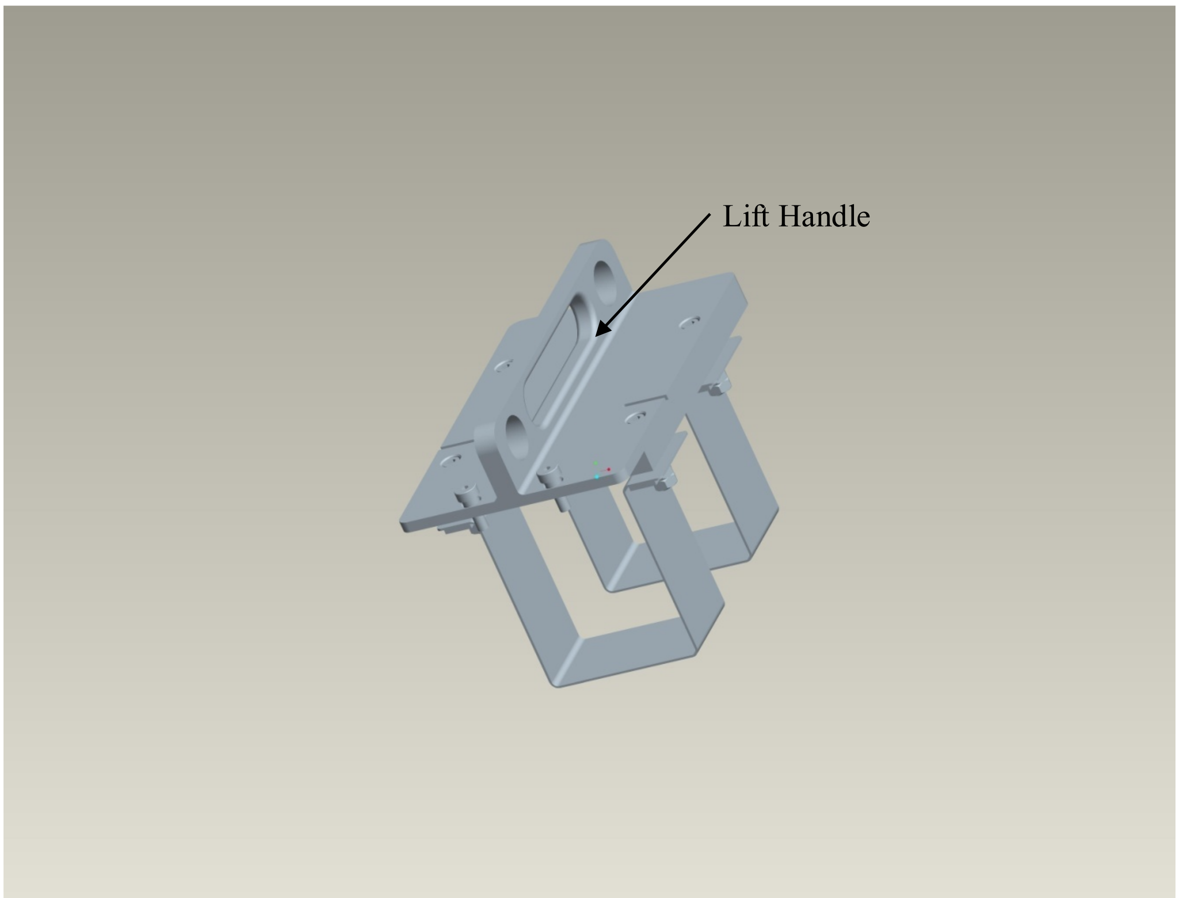
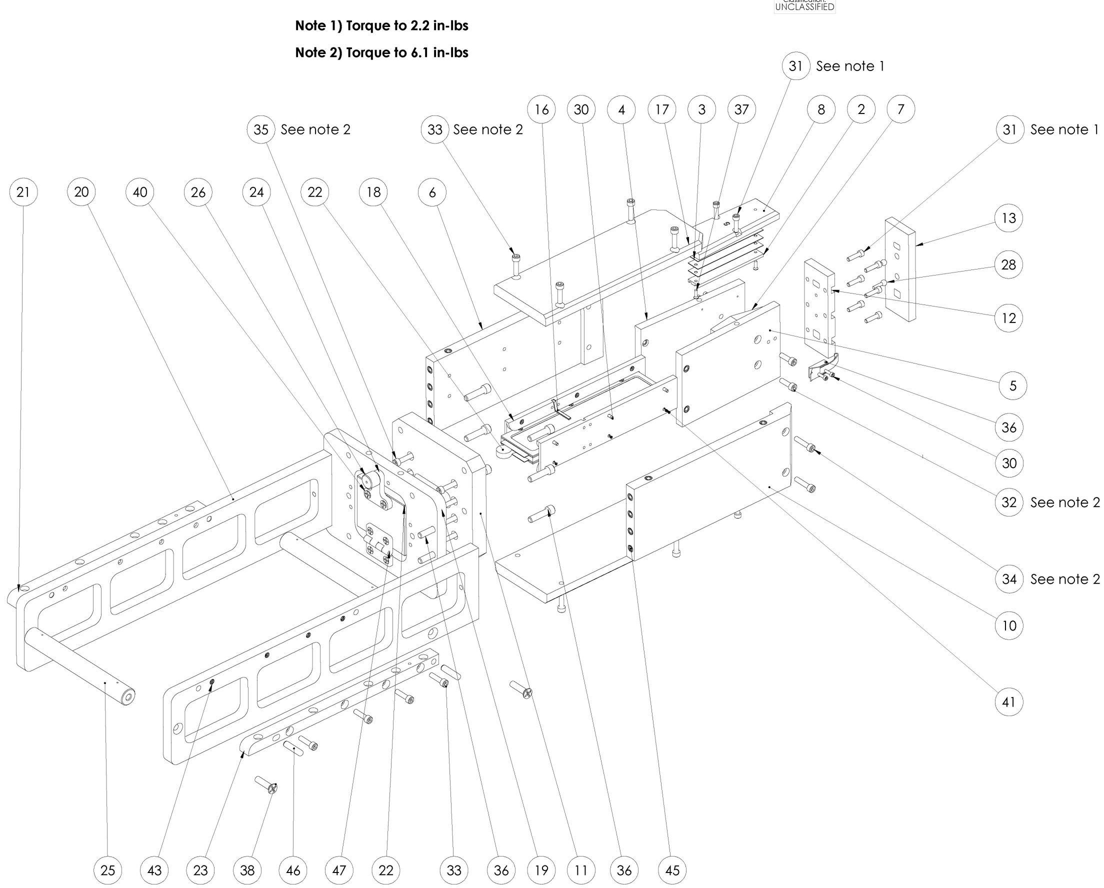


Fig. G-1. HOPG Lifting Handle.

Appendix D – HOPG Drawings

Classification: UNCLASSIFIED



ITEM NO.	DESCRIPTION	QTY
1	12X50mm HOPG crystal	1
2	Crystal mount	1
3	Crystal shim	3
4	Side plate, left	1
5	Side plate, right	1
6	left rear side plate	1
7	Beam block	1
8	Crystal cover	1
9	Crystal cover	1
10	Right rear side plate	1
11	Rear lead shield	1
12	Front plate	1
13	Front shield	1
14	IP cassette	1
15	#4-40X.188" FHMS	12
16	Fiducial	2
17	rear top/bottom cover	2
18	IP cassette guide	2
19	TIM mounting plate	1
20	TIM mounting rail	2
21	Top left mounting rail	1
22	IP access door	1
23	Top right mounting rail	1
24	Door bracket	1
25	Standoff	2
26	Vented captured thumb screw	1
27	Southco latch #97-30-160-12	2
28	.25" tooling ball Reid tool # STB-26705	2
29	Hinge, Southco 4A-4V4-24	1
30	#4-40X.375" SHCS	13
31	#8-32X.625" SHCS	10
32	#10-32X.625" SHCS	4
33	#10-32X.75" SHCS	16
34	#10-32X.875" SHCS	4
35	#10-32X1" SHCS	8
36	.25"-20X1" SHCS	12
37	#4-40X.375" FHS	2
38	.25"-20X1" FHMS	4
39	#10-32-.5" FHMS	4
40	#8-32X.5" FHMS	6
41	#4-40 X .168 helicoil Reid tool TI-80	12
42	#8-32 X .246" helicoil, Reid tool TI-170	6
43	#10-32 X .38" helicoil Reid Tool TI-2150	8
44	#8-32 heavy wall threaded insert, Reid tool KLI-71300	4
45	#10-32 thinwall threaded insert, Reid Tool KLI-71521	24
46	.25"X1" dowel pin	4

INCH
Third angle projection

Lawrence Livermore National Laboratory

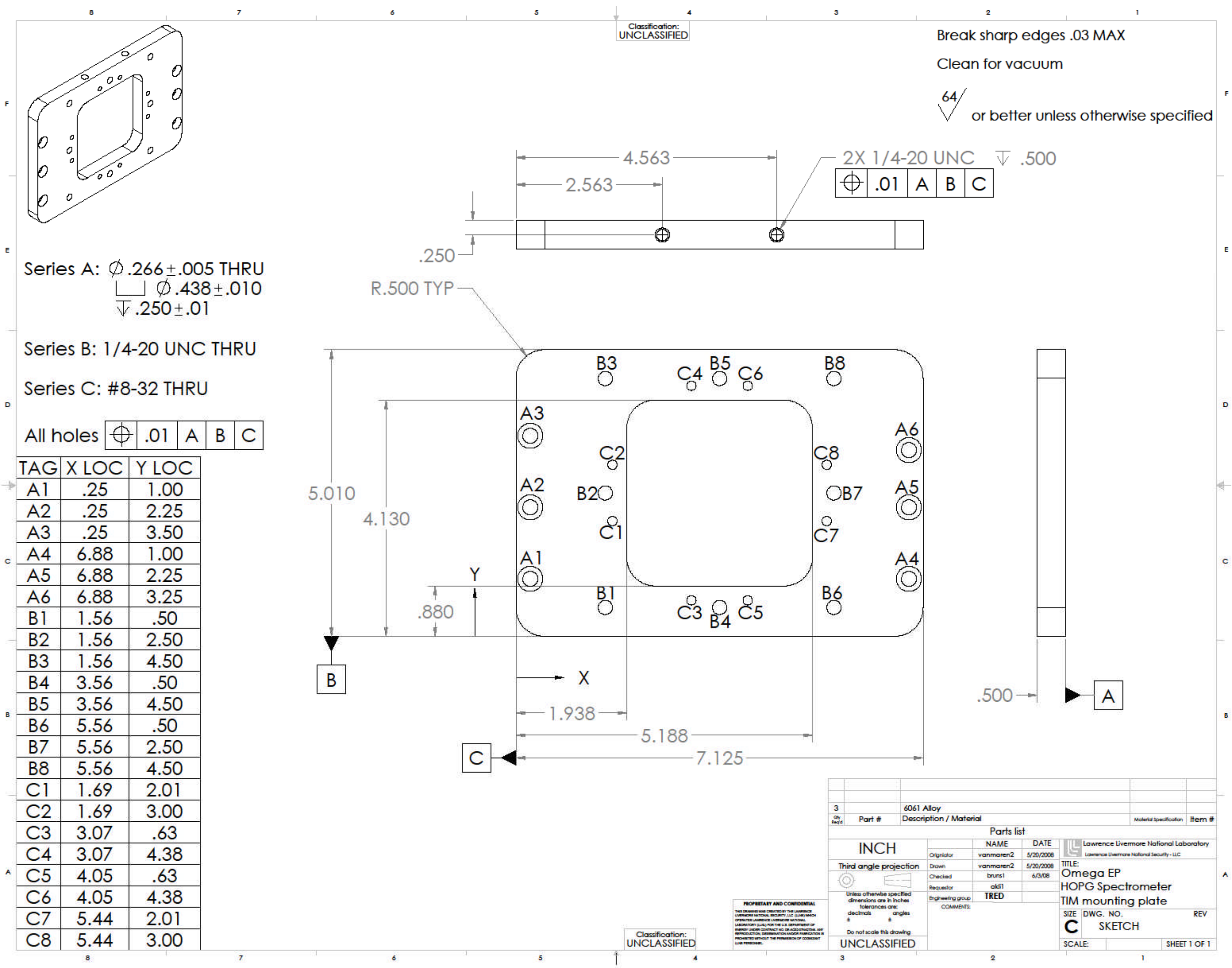
TITLE: Omega EP DC-HOPG spectrometer

SIZE D SKETCH

SHEET 1 OF 1

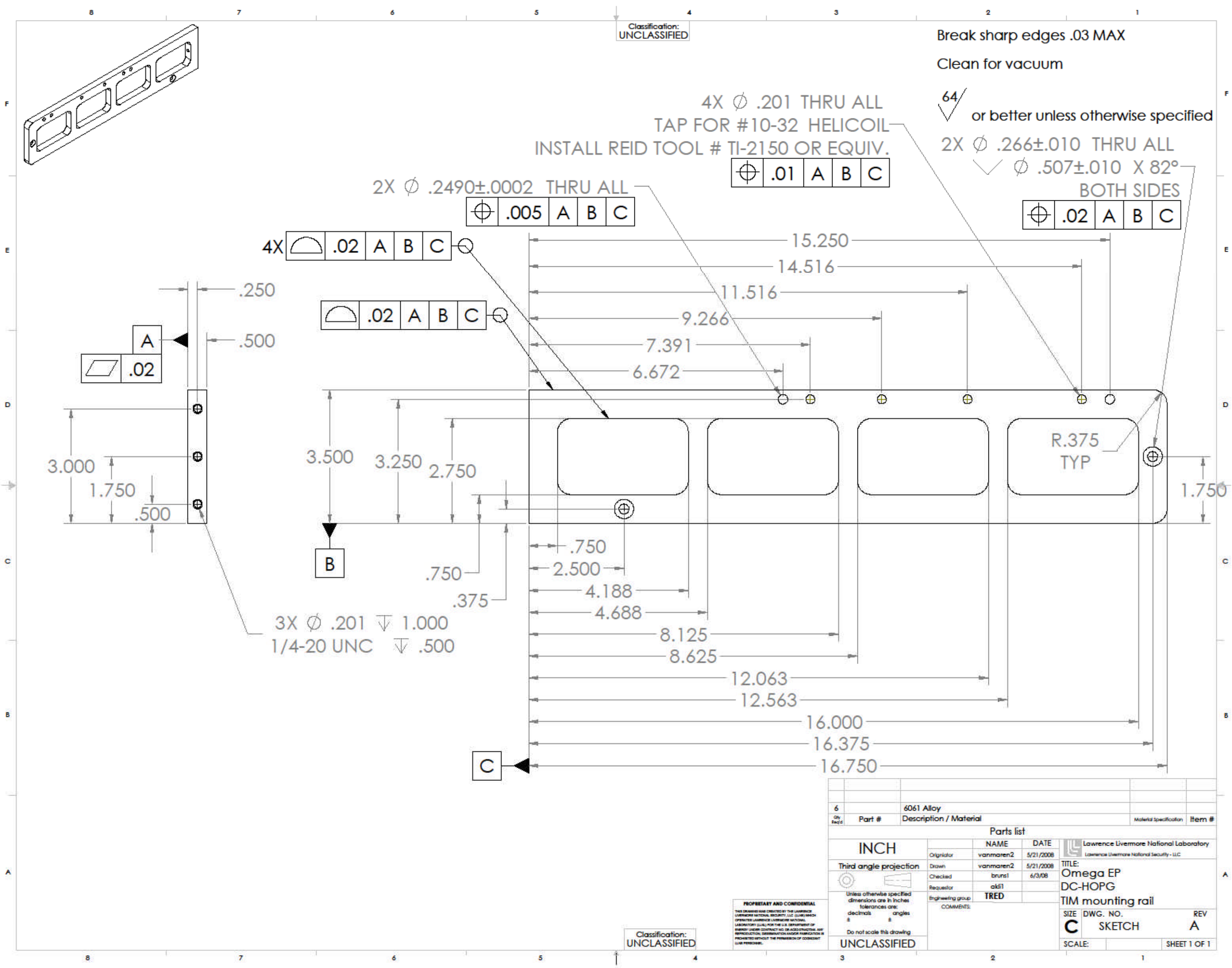
UNCLASSIFIED

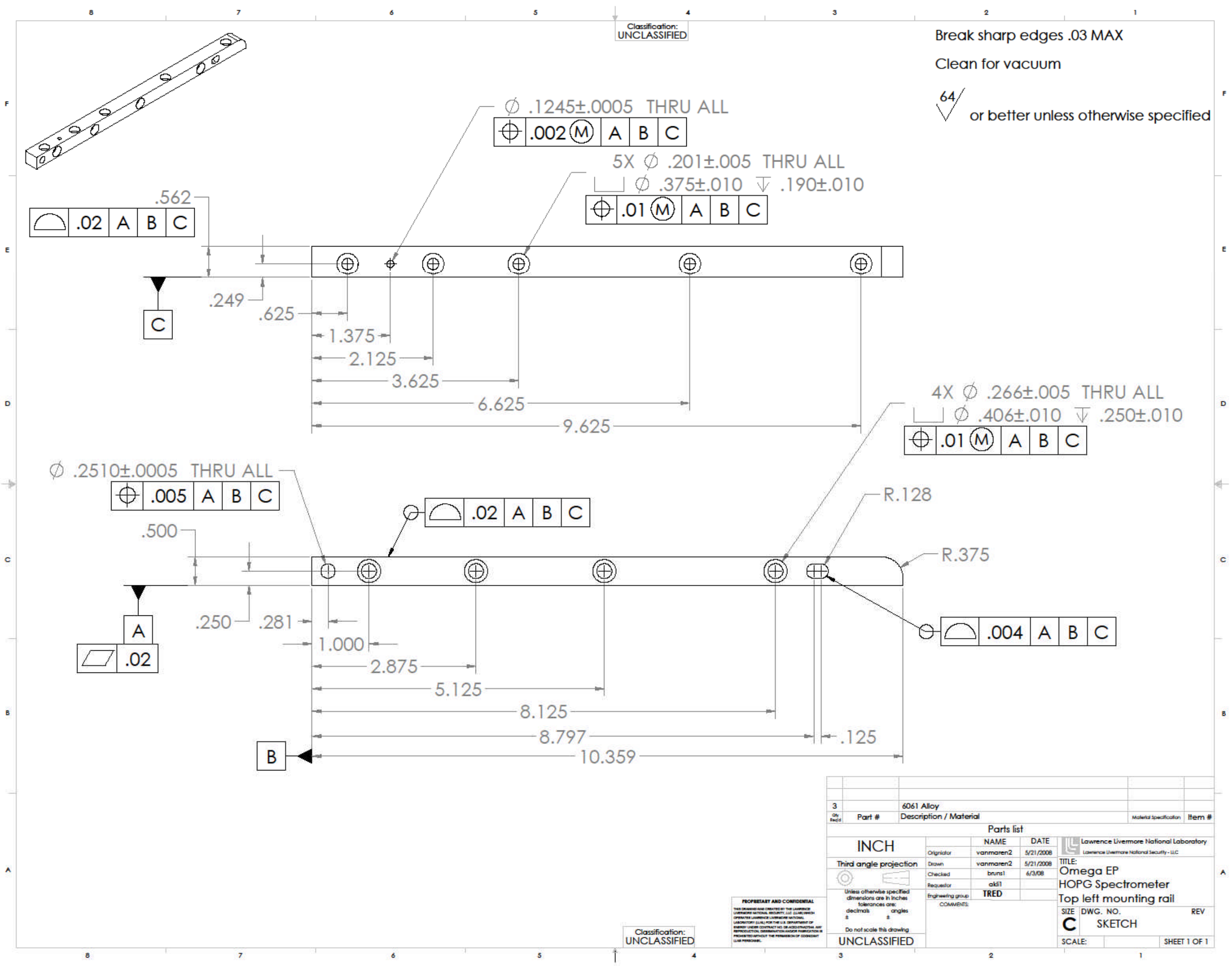
Classification: UNCLASSIFIED



TAG	X LOC	Y LOC
A1	.25	1.00
A2	.25	2.25
A3	.25	3.50
A4	6.88	1.00
A5	6.88	2.25
A6	6.88	3.25
B1	1.56	.50
B2	1.56	2.50
B3	1.56	4.50
B4	3.56	.50
B5	3.56	4.50
B6	5.56	.50
B7	5.56	2.50
B8	5.56	4.50
C1	1.69	2.01
C2	1.69	3.00
C3	3.07	.63
C4	3.07	4.38
C5	4.05	.63
C6	4.05	4.38
C7	5.44	2.01
C8	5.44	3.00

Title Dual Channel Highly Oriented Pyrolytic Graphite Diagnostic II





Classification: UNCLASSIFIED
Break sharp edges .03 MAX
Clean for vacuum
64
or better unless otherwise specified
Ø .1245±.0005 THRU ALL
.002 Ⓜ A B C
5X Ø .201±.005 THRU ALL
Ø .375±.010 ↧ .190±.010
.01 Ⓜ A B C
.562
.02 A B C
C
.249
.625
1.375
2.125
3.625
6.625
9.625
4X Ø .266±.005 THRU ALL
Ø .406±.010 ↧ .250±.010
.01 Ⓜ A B C
Ø .2510±.0005 THRU ALL
.005 A B C
.02 A B C
R.128
R.375
.500
A
.02
.250
.281
1.000
2.875
5.125
8.125
8.797
.125
10.359
B
.004 A B C
3
6061 Alloy
Part #
Description / Material
Item #
Parts list
INCH
Third angle projection
NAME
DATE
vanmaren2
vanmaren2
bruns1
TRED
Lawrence Livermore National Laboratory
TITLE:
Omega EP
HOPG Spectrometer
Top left mounting rail
SIZE
DWG. NO.
REV
C
SKETCH
SCALE:
SHEET 1 OF 1
Do not scale this drawing
UNCLASSIFIED
Classification: UNCLASSIFIED

The Following drawings are available through ECMS:

IP Access Door	AAA09-504865-AA
Rear Lead Shield	AAA09-504866-AA
Crystal Cover, Copper	AAA09-504858-AA
Crystal Cover, Silver	AAA09-504859-AA
Side Plate, Left	AAA09-504860-AA
Side Plate, Right	AAA09-504861-AA
Right Rear Side Plate	AAA09-504862-AA
Left Rear Side Plate	AAA09-504863-AA
Rear Top/Bottom Cover	AAA09-504864-AA